

VARIATION, REPETITION, AND CHOICE

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Experiment 1 investigated the controlling properties of variability contingencies on choice between repeated and variable responding. Pigeons were exposed to concurrent-chains schedules with two alternatives. In the REPEAT alternative, reinforcers in the terminal link depended on a single sequence of four responses. In the VARY alternative, a response sequence in the terminal link was reinforced only if it differed from the n previous sequences (lag criterion). The REPEAT contingency generated low, constant levels of sequence variation whereas the VARY contingency produced levels of sequence variation that increased with the lag criterion. Preference for the REPEAT alternative tended to increase directly with the degree of variation required for reinforcement. Experiment 2 examined the potential confounding effects in Experiment 1 of immediacy of reinforcement by yoking the interreinforcer intervals in the REPEAT alternative to those in the VARY alternative. Again, preference for REPEAT was a function of the lag criterion. Choice between varying and repeating behavior is discussed with respect to obtained behavioral variability, probability of reinforcement, delay of reinforcement, and switching within a sequence.

Key words: variation, choice, concurrent-chains schedules, key peck, pigeons

Two lines of operant research, both concerned with the controlling sources of behavioral variability, have challenged the conclusion that behavioral stereotypy is an inherent and inevitable result of contingencies of reinforcement (e.g., Schwartz, 1980, 1982a, 1982b). One line, characterized by the absence of operant contingencies between response variation and reinforcement, has shown a negative correlation between reinforcement rate and degree or amount of variability in steady-state performance (e.g., Antonitis, 1951; Eckerman & Lanson, 1969; Notterman & Mintz, 1965; Tatham, Wanchis-

en, & Hineline, 1993). The other line has asserted that variability itself can be selected by contingencies of reinforcement. That is, specifying that a given response sequence must differ from those emitted recently results in greater variation in the sequences than occurs in the absence of such a requirement (e.g., Page & Neuringer, 1985). This outcome has been functionally related to a number of variables, such as reinforcement history (Hunziker, Caramori, da Silva, & Barba, 1998) and response topography (Morgan & Neuringer, 1990).

Behavioral variability also has been investigated in the context of choice. To demonstrate that “pigeons choose systematically to vary and to repeat their behaviors” (Neuringer, 1992, p. 249), Neuringer trained pigeons to vary or repeat sequences of four responses. VARY was defined when the current sequence differed from the three previous ones and REPEAT was defined when the sequence was equal to any one of the previous three sequences. Before each sequence occurred, a computer selected whether VARY or REPEAT would be reinforced. The probability of reinforcement of VARY or REPEAT was varied over conditions such that the probabilities of REPEAT reinforcement were equal to 1.0 minus the VARY probability. The percentages of VARY sequences emitted were an increasing function of the probability of VARY reinforcement. Neuringer interpreted these findings as evidence that choice between varying ver-

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sus repeating response sequences was controlled by reinforcement probability, a variable that he also described in terms of relative frequency of reinforcement.

Fantino (1977) noted that in concurrent schedules, the index of preference, or relative rate of response, is confounded by the direct reinforcement of the two concurrent responses. For example, FR schedules maintain higher response rates than VI schedules. Consequently, when these two schedules are concurrently arranged, higher FR rates do not necessarily indicate preference for that schedule. In Neuringer's (1992) experiment, although he claimed to be investigating choice between varying and repeating contingencies, one cannot assert preference for either contingency because the index of preference, the ratio of VARY to REPEAT sequences, was confounded with the effects of reinforcement of those sequences. That is, because the percentage of VARY sequences was a direct function of the probability of VARY reinforcers, this index may have changed either because the pigeons actually preferred one or the other type of sequence or it may have changed because of the direct action of reinforcement on the sequences. Fantino proposed that a better index of preference could be obtained by using concurrent-chains schedules because choice could be separated from the response patterns that are directly reinforced.

Following Fantino's (1977) observation, the present experiments used concurrent-chains schedules to assess preference for VARY and REPEAT sequences as a function of the required degree of variability. This allowed an assessment of whether, as Neuringer's (1992) data suggest, the degree of variability is a factor in determining preference. With this procedure it also was possible to investigate such preferences while holding overall reinforcement rate constant.

Choice between variation and repetition also was of interest for two reasons. First, its demonstration would provide further evidence of the sensitivity of sequences of responses to their consequences and, as a result, of the general idea of variation and repetition as dimensions of the operant. Second, such sensitivity is predicted by recent findings. Doughty and Lattal (2001) showed that variability was more resistant to disruption

by prefeeding or response-independent food delivery during blackouts than was repeatability. Nevin and Grace (2000) found that pigeons' preferences were greater for those response alternatives that were more resistant to disruption by response-independent food and to extinction (see also Grace & Nevin, 1997). If variable behavior is more resistant to disruption than repetitive behavior, and if contingencies correlated with greater resistance are preferred over those generating less resistance, then it follows that variability and repeatability contingencies should differentially control preference.

EXPERIMENT 1

Using a concurrent-chains schedule, Experiment 1 investigated choice between VARY and REPEAT contingencies as a function of the degree of behavioral variability required by the contingencies. At issue was whether choice between varying and repeating sequences of responses could be predicted and controlled by the level of sequence variability. If the variability requirement is a good predictor of preference, a systematic relation between preference and behavior variation should be observed.

METHOD

Subjects

Four experimentally naive White Carneau pigeons (P10, P20, P30, and P40) were maintained at 75% to 80% of their free-feeding weights throughout the experiment. The pigeons were housed individually with free access to grit and water in a temperature-controlled room with a 12:12 hr light/dark cycle. Supplementary food was given 1 hr after the end of the session as necessary to maintain prescribed weights.

Apparatus

The experimental chamber had a workspace measuring 29.5 cm long, 31 cm deep, and 32 cm high. Four 2.8 cm diameter, translucent keys were displayed horizontally on the work panel, 22 cm above the floor, with 9 cm separating the two middle keys and 3 cm separating each of the outermost keys. The keys are identified here, from left to right, as Keys 1, 2, 3, and 4. The keys were transilluminated

by red, white, or green lights. Pecks on an illuminated key at a minimum force of 0.14 N operated the key. A Gerbrands food magazine delivered mixed grain through an aperture (4.5 cm by 6 cm) centered in the middle of the work panel and located 7.5 cm above the floor. A white houselight was located in the lower-right corner of the work panel. The houselight and the keys were darkened and inoperative during 3-s grain presentations, when the hopper was illuminated by a white light. A Sonalert® tone generator, located behind the work panel, provided an auditory stimulus. The chamber was housed in a light- and sound-attenuating box equipped with a fan for ventilation and masking noise. A Tandy 1000 TX microcomputer connected to the chamber by a MED-PC® interface system arranged the experimental conditions and recorded the pigeons' responding. MED-PC® software was used to program the experimental contingencies.

Procedure

Preliminary REPEAT/VARY training. Previous studies have shown that, when variability is not demanded, the most frequent four-response sequence is one of responding on a single operandum, followed by the LRRR and RLLL (L for left-key responses and R for right-key responses) sequences (McElroy & Neuringer, 1990; Morgan & Neuringer, 1990). Based on that finding, the REPEAT sequence throughout this study was LRRR; the LLLL or RRRR sequences were not selected to require the use of both keys during the REPEAT and VARY conditions.

The training of the REPEAT sequence occurred in several stages, and was similar to that provided by Cohen, Neuringer, and Rhodes (1990). During the REPEAT training, two keys were white: Keys 1 (left) and 2 (right) for Pigeons P30 and P40, and Keys 3 (left) and 4 (right) for Pigeons P10 and P20. In Stage 1, only the right key was illuminated. Two consecutive right-key responses were required for reinforcement. In Stage 2, reinforcers followed three consecutive right-key responses. In Stage 3, the left key was initially illuminated. A left-key response darkened that key and illuminated the right key. Three consecutive right-key responses resulted in reinforcement. In Stage 4, both left and right keys were illuminated simultaneously. One

left-key response followed by three right-key responses resulted in reinforcement. Left-key responses after the first left-key response, and right-key responses at the beginning of the session or after reinforcement, had no consequences. A left-key response after the first right-key response initiated a 5-s blackout (BO) during which the chamber was dark and the Sonalert was on continuously. In Stage 5, the reinforcement contingencies were similar to those in Stage 4 except that the BO also followed right-key responses at the beginning of the session or after reinforcement. In Stage 6, reinforcement was contingent upon the emission of the LRRR sequence. Any response that disrupted this sequence immediately produced the BO. In Stage 7, the LRRR sequence was required for reinforcement but now BOs occurred only at the end of a four-response sequence. Thus any other sequence of four responses terminated in BO. During these stages, each of the first three key pecks was followed by a 0.5 s darkening of the response key. Responses to the darkened key and during the BO reset the interval and were not counted towards the REPEAT contingency (cf. Neuringer, 1991). Reinforcement and BO were immediately followed by a new trial. Each session ended after 60 reinforcers.

When at least 50% of the REPEAT sequences were reinforced for three consecutive sessions, the VARY contingency was introduced. During this contingency, two keys were green: Keys 1 and 2 for Pigeons P10 and P20, and Keys 3 and 4 for Pigeons P30 and P40. Each VARY sequence consisted of four responses, with each of the first three responses producing a 0.5 s darkening of the response key. A sequence was reinforced if it met the variability criterion; otherwise it initiated a 5-s BO during which tone alternated with no tone every 500 ms. The VARY sequences included the sequence that was always used in REPEAT and also sequences that used only one key. The VARY contingency alternated with the REPEAT contingency according to a multiple schedule. Initially, each session began with the REPEAT contingency. When 10 REPEAT reinforcers were obtained, the VARY contingency then operated for 50 reinforcers. This difference in the frequency of VARY and REPEAT reinforcers per session was implemented because, prior to this point in the ex-

periment, the pigeons had accumulated more reinforcers for REPEAT sequences than for VARY sequences. When the total numbers of VARY and REPEAT reinforcers obtained since the beginning of training was approximately the same, sessions began randomly with either the REPEAT or VARY component. Each component lasted until 10 reinforcers had been earned, and was followed by a 5-s intercomponent interval during which the chamber was dark, but unlike the BOs, no tone was presented. Each session lasted for 60 reinforcers throughout the REPEAT/VARY training.

Across three training conditions, the degree of variability required for reinforcement was manipulated according to a lag procedure (Page & Neuringer, 1985). To be reinforced in the VARY component, a sequence had to differ from the immediately preceding sequence (Lag 1 criterion), from each of the last three sequences (Lag 3 criterion), or from each of the five previous sequences (Lag 5 criterion) in different conditions of the experiment. Each lag criterion remained in effect until at least 50% of the VARY and 50% of the REPEAT sequences were reinforced over three consecutive sessions. The preliminary training typically was completed within 90 sessions.

Concurrent-chains training. Figure 1 illustrates the concurrent-chains procedure used to investigate preference for VARY versus REPEAT contingencies. In the initial links, Keys 2 and 3 were red, and a concurrent variable-interval (VI) 30-s VI 30-s schedule was programmed according to Stubbs and Pliskoff's (1969) procedure. Thus the VI schedules, generated according to the Fleshler and Hoffman (1962) progression with 12 intervals, operated interdependently. That is, after an average of 30 s, a terminal link entry was arranged on either Key 2 or Key 3. A single peck on the appropriate key initiated its terminal link; pecks on the other key were ineffective. Once a terminal link entry was assigned, the VI timer stopped until the end of the intertrial interval (ITI).

REPEAT and VARY contingencies were available in the terminal links. The arrangement of these contingencies was similar to that in the REPEAT/VARY training. With both contingencies, each trial consisted of a sequence of four responses. Each of the first

three responses darkened the keylight for 0.5 s. Responses to either darkened key reset the 0.5-s period, but these responses were not counted toward the sequence requirement. The fourth response terminated the trial. If the sequence requirement was met, a 3-s reinforcer ensued. Otherwise, a 5-s BO occurred, during which the chamber was dark, the keys were inoperative, and a continuous (REPEAT condition) or intermittent (VARY condition) tone was presented. Responses during the BO reset the 5-s interval. A new trial began immediately after the reinforcer or BO.

During REPEAT terminal links, the keys were white, and reinforcement was contingent on the occurrence of a single sequence (LRRR). During VARY terminal links, the keys were green, and a Lag n variability condition operated such that a sequence was reinforced only if it differed from the previous n sequences. Each terminal link remained in effect until five reinforcers were obtained. To maintain a constant overall reinforcement rate, a timeout (TO) was added after the fifth reinforcer for the shorter terminal link, which was always the REPEAT one, such that the total time in both terminal links was equal. The TO duration was determined within each session. For example, if it took the pigeon 50 s to complete the VARY terminal link, but only 30 s to complete the REPEAT terminal link, an additional 20-s period was introduced after the fifth REPEAT reinforcer was delivered (see Figure 1). During the TO, the keylights were off but the houselight remained on. The delivery of the fifth reinforcer, or the end of the TO, initiated a 5-s ITI, followed by the start of another initial link. The ITI and BO were similar except that: (a) ITIs did not include the presentation of the tone, and (b) ITIs occurred at the end of the terminal link whereas BOs occurred after incorrect sequences. The first two terminal links of the concurrent-chains schedule in each session were forced ones, with one occurrence of either the VARY or the REPEAT components randomly ordered across sessions. They were considered warm-up terminal links and were excluded from the data analysis.

For Pigeons P10 and P20, pecks on the left initial-link key (Key 2) produced the VARY terminal link that operated on Keys 1 and 2

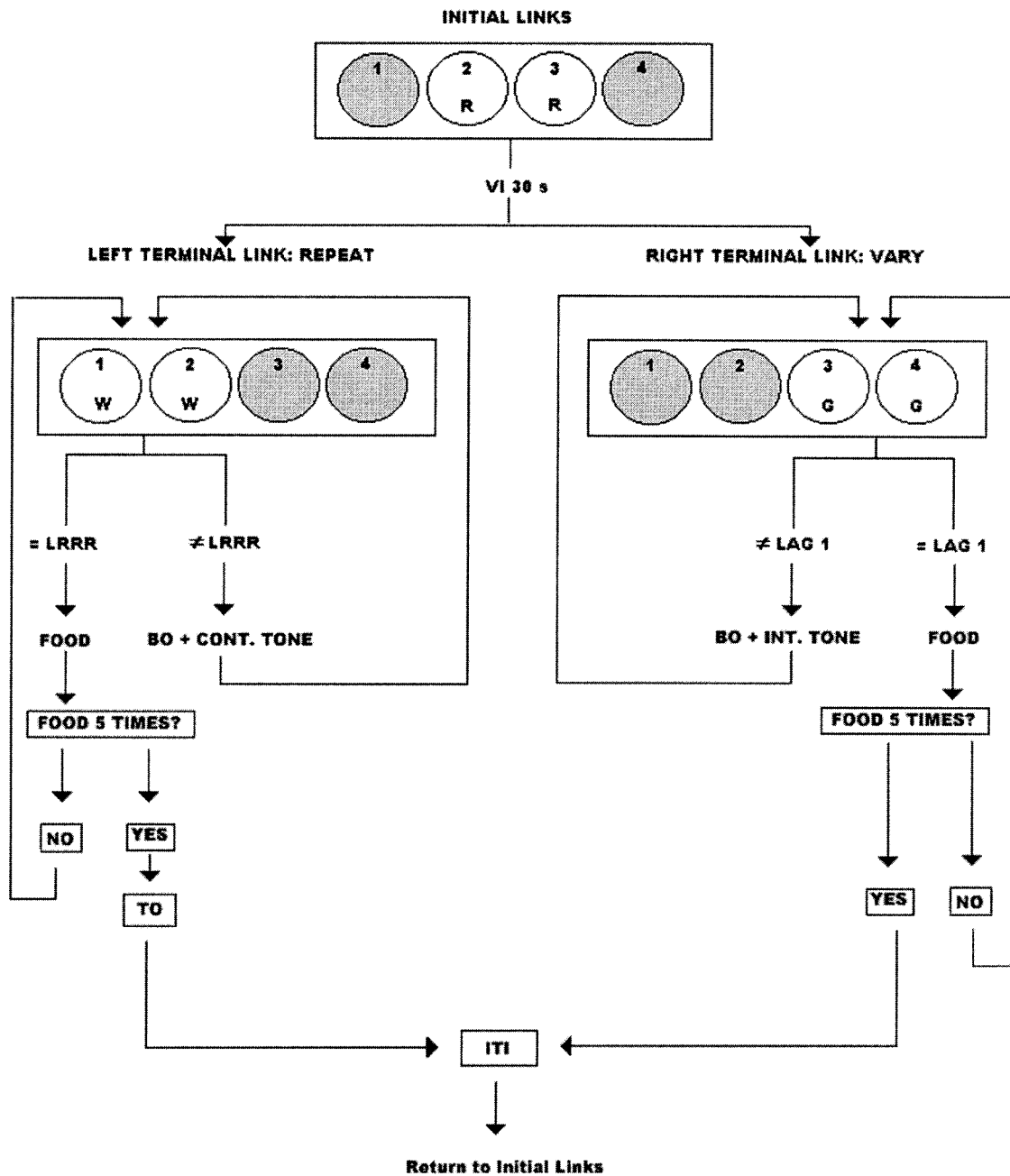


Fig. 1. Schematic diagram of the concurrent-chains schedule in Experiment 1.

whereas pecks on the right initial-link key (Key 3) led to the REPEAT terminal link, which was in effect on Keys 3 and 4. For Pigeons P30 and P40, left initial-link key responses initiated the REPEAT terminal link (Keys 1 and 2) whereas right initial-link key

responses initiated the VARY terminal link (Keys 3 and 4).

Table 1 shows the order of experimental conditions and the number of sessions per condition. The lag variability criterion in the VARY terminal link was manipulated across

Table 1

Total number of sessions and average number of sequences per reinforcer for the REPEAT and VARY terminal links in each condition of Experiment 1. Data are averaged over six sessions. Standard deviations are shown in parenthesis.

Subjects	Conditions	Sessions	Sequences per reinforcer	
			Repeat	Vary
P10	Lag 5	32	1.1 (0.1)	1.8 (0.3)
	Lag 1	31	1.1 (0.1)	1.3 (0.1)
	Lag 10	36	1.1 (0.1)	2.1 (0.2)
	Lag 5	35	1.2 (0.1)	1.6 (0.2)
P20	Lag 5	48	1.1 (0.0)	1.9 (0.2)
	Lag 1	36	1.1 (0.1)	1.2 (0.1)
	Lag 10	34	1.1 (0.1)	2.5 (0.2)
	Lag 5	33	1.1 (0.1)	1.7 (0.1)
P30	Lag 5	35	1.3 (0.1)	1.7 (0.2)
	Lag 10	30	1.3 (0.1)	2.4 (0.4)
	Lag 1	32	1.4 (0.2)	1.5 (0.1)
	Lag 5	35	1.3 (0.1)	1.7 (0.2)
P40	Lag 5	38	1.3 (0.1)	1.5 (0.1)
	Lag 10	32	1.4 (0.1)	2.5 (0.3)
	Lag 1	34	1.2 (0.1)	1.1 (0.1)
	Lag 5	33	1.1 (0.4)	1.5 (0.1)

experimental conditions. In the initial condition, the pigeons were exposed to a Lag 5 criterion. Two pigeons then were exposed to Lag 1 followed by Lag 10, and the remaining 2 to Lag 10 followed by Lag 1. Finally, all pigeons were returned to Lag 5. Each lag requirement was in effect until the relative number of responses in the initial link (REPEAT responses/total responses), averaged over three sessions, differed by no more than 0.05 from the average of the three previous sessions. Sessions were conducted 6 days a week. Each session ended after eight left and eight right terminal links, excluding warm-up terminal links.

RESULTS

The following analysis is based on choice outcomes followed by REPEAT and VARY performances in the terminal links during the last six sessions of each condition.

Performance in the Initial Links

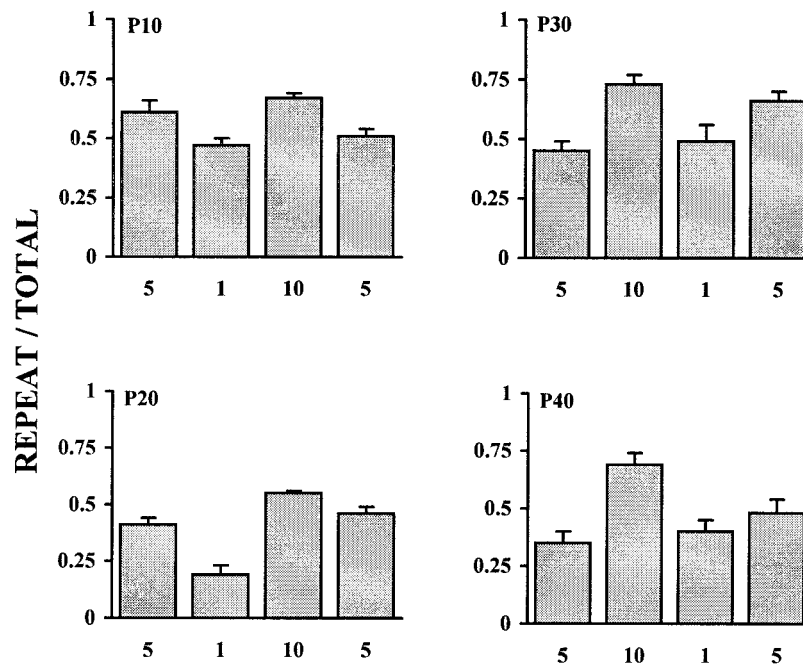
Figure 2 shows the results on choice between varying and repeating contingencies. Choice was measured by dividing the number of responses in the initial-link key correlated with the REPEAT terminal link by the total number of responses in the initial link. Choice proportions of 0.5 indicate that responding was distributed equally between the REPEAT and VARY keys. Higher proportions indicate greater responding on the REPEAT key. Preference for the REPEAT terminal link was least with the Lag 1 requirement and greater with the Lag 10 requirement in the VARY component. The Lag 1 and Lag 5 preferences sometimes overlapped. That is, the direction of the shifts in preference for REPEAT tracked the lag criterion such that a direct relation between preference for the REPEAT terminal link and the extreme values of the lag requirement (Lag 1 and Lag 10) was obtained.

Performance in the Terminal Links

In that one purpose of Experiment 1 was to evaluate the suitability of concurrent-chains schedules to study choice between varying and repeating responses, the main requirement was that the REPEAT and VARY contingencies produced distinct terminal-link performances. Figure 3 shows U values for each pigeon across conditions. The U value is an index of overall sequence variability calculated according to the following equation:

$$U = - \sum \frac{pi \times [\log(pi)/\log(2)]}{\log(n)/\log(2)}, \quad (1)$$

where p is the probability of occurrence of sequence i , and n is the number of possible sequences, or 16 (Neuringer, 1991; Page & Neuringer, 1985). According to the U statistic, if each of the 16 possible sequences were emitted equally often in a given session, then U would be equal to 1; if only one sequence was emitted, U would be equal to 0. The degree of behavioral variability engendered by REPEAT contingencies (open bars) was



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Fig. 2. Proportion of REPEAT choices in the initial links for each condition of Experiment 1. Data are averaged over six sessions. Error bars represent one standard deviation.

much lower than that obtained with VARY contingencies (filled bars), with REPEAT generating low and approximately constant U values for all pigeons, and VARY producing U values that changed with the lag criterion for Pigeons P10, P20, and P30. For these pigeons, the Lag 1 condition engendered less sequence variation than the Lag 5 condition, which tended to engender levels of sequence variation close to those observed for the Lag 10 condition. Sequence variability of Pigeon P40 was high regardless of the lag manipulations in the variability requirement.

Figure 4 shows the percentage of correct sequences in the REPEAT (open bars) and VARY (filled bars) terminal links for each pigeon in each condition. This measure was calculated by dividing the number of sequences that met the REPEAT (or the VARY) requirement by the total number of REPEAT (or VARY) sequences in a session, and then multiplying the result by 100. The percentage of correct sequences was greater in the REPEAT than in the VARY terminal link across conditions, with the exception of the Lag 1 con-

dition for Pigeon P40. The percentage of REPEAT correct sequences was constant throughout the experiment whereas the percentage of VARY correct sequences changed inversely with manipulations in the lag criterion.

Taken together, Figures 3 and 4 indicate that, with more stringent criteria, VARY behavior tended to be more variable, but such variation was not necessarily followed by greater reinforcement. Across conditions, under static contingencies, REPEAT behavior remained both stereotyped and effective in producing reinforcement.

To examine further the performance in the terminal links, the percentage of occurrence of each of the 16 possible sequences in the VARY terminal links under each experimental condition is plotted in Figure 5. Congruent with the U values of Figure 3, frequency distributions varied with the lag criterion, except for Pigeon P40. The Lag 10 condition produced the flattest, and the Lag 1 condition the sharpest, frequency distributions. An alternative way to summarize

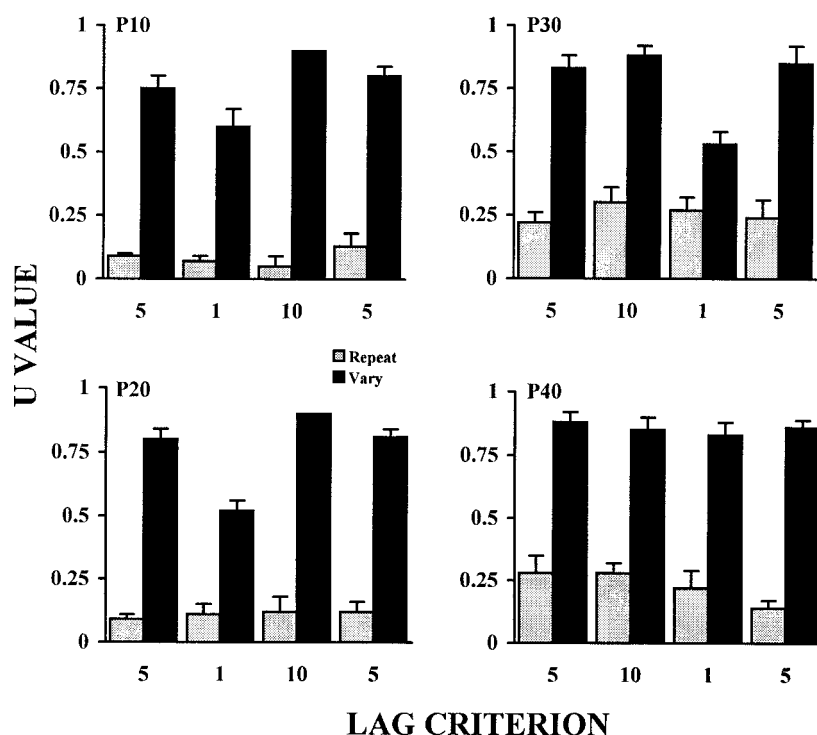


Fig. 3. U values in the REPEAT (open bars) and VARY (filled bars) terminal links for each condition of Experiment 1. Data are averaged over six sessions. Error bars represent one standard deviation.

the variability shown in Figure 5 is to consider each pigeon's four most frequently emitted sequences as a percentage of total sequence occurrences. As lag increased, this percentage tended to decrease. Across Lags 1, 5 (averaged across determinations), and 10, respectively, the percentages were: for Pigeon P10, 86.1%, 58%, and 37.2%; for Pigeon P20, 91.5%, 56.1%, and 44.2%; for Pigeon P30, 88.0%, 47.1%, and 42.3%; and for Pigeon P40, 48.1%, 44.7%, and 44.2%.

There is evidence that the stereotypy in the VARY terminal link during the Lag 1 and Lag 5 conditions may reflect efficient responding as long as such stereotypy comprises sequences with minimal switching. Figure 6 presents the relative frequency distributions of the number of switches per sequence for the VARY responding across conditions. Individual and average data are shown in the left and right columns, respectively. The binomial distribution predicted by random responding, that is, when the 16 possible sequences occur equally often, is also presented in the right column

(dashed function). The left column indicates that intersubject differences in the switching distribution tended to decrease as the lag criterion increased. With Lag 1, the emission of any two sequences in an alternated order would produce the reinforcer, and because there were 16 possible sequences, the two selected sequences were expected to be different across subjects. With Lag 10, however, several different sequences (at least 11) were required for reinforcement such that sequence overlapping across subjects would be the rule. The right column shows that under all lag contingencies, one-switch sequences occurred more often than sequences incorporating zero, two, or three switches. In the Lag 1 condition, mean performance tended to deviate from random in that zero-switch sequences were over represented and two-switch and three-switch sequences were under represented. As the lag criterion increased, performance increasingly approximated the random distribution.

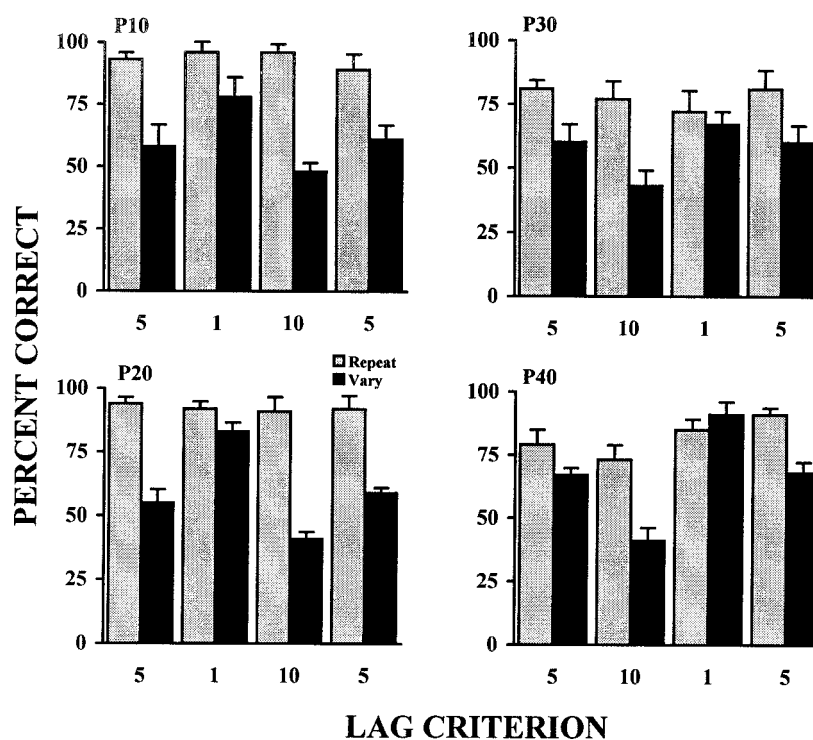


Fig. 4. Percentage of reinforced sequences in the REPEAT (open bars) and VARY (filled bars) terminal links for each condition of Experiment 1. Data are averaged over six sessions. Error bars represent one standard deviation.

Choice Versus Performance in the Terminal Links

Figure 7 shows the log proportion of REPEAT choices in the initial links as a function of the log proportion of REPEAT reinforced sequences in the terminal link. Solid lines are fitted least-squares regression lines. The equation of the fitted line ($y = ax + b$, where a is the slope and b is the intercept) appears in each graph. Preference for REPEAT increased as the relative percentage of reinforced sequences in the REPEAT terminal link increased. The slope values showed that proportional changes in REPEAT preference were greater than proportional changes in the percentage of reinforced sequences. The R^2 values ranged from .52 to .95, suggesting that changes in preference may be accounted for by the relative probability of REPEAT versus VARY reinforcement in the terminal links.

An analysis of log proportion of REPEAT choices as a function of log proportions of U values in the REPEAT terminal links, not shown here, revealed the lack of a systematic relation between preference and the ob-

tained level of behavioral variability for all pigeons.

DISCUSSION

Choice was a direct function of the degree of variability required by the VARY contingency. This finding is consistent with Neuringer's (1992) suggestion that pigeons choose to vary and repeat, but the present use of a concurrent-chains schedule demonstrates such preference in the absence of the confounding effects of the direct action of the reinforcement contingency on the choice responses. Although overall reinforcement rate was held constant, thereby eliminating this variable as a source of control, several other indirect variables (Zeiler, 1977) also might have contributed to the choice along with the direct variable of variability requirements.

If behavioral variability per se influences choice, a systematic relation between the U value and preference must be obtained. The results obtained with Pigeon P40 indicated that preference changed even though the U values remained constant across conditions.

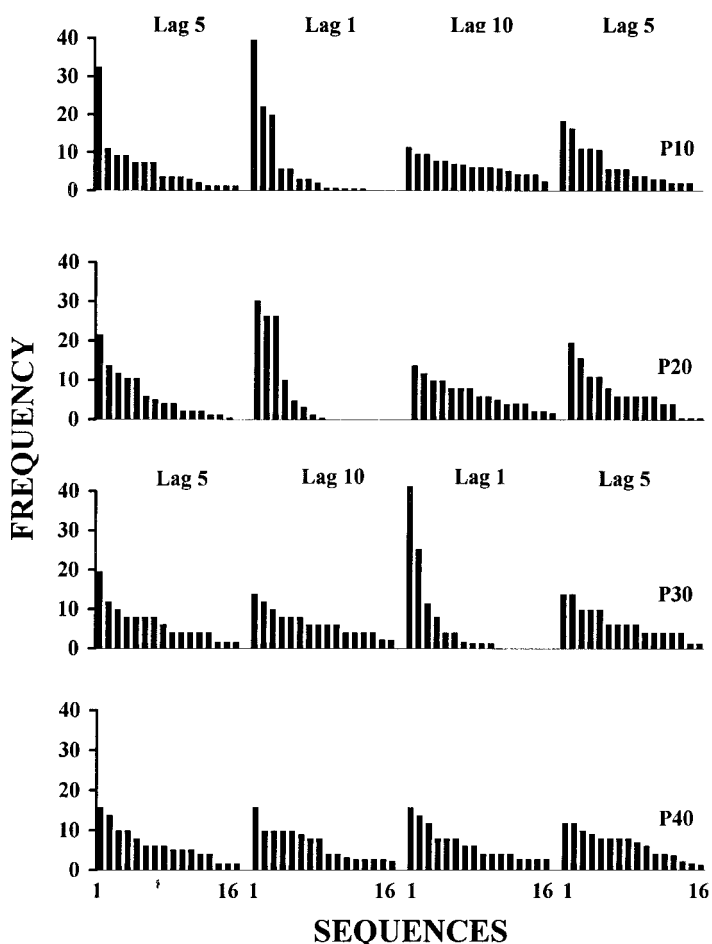


Fig. 5. Frequency distributions of the 16 possible sequences in the VARY terminal link in Experiment 1. In each graph, and for each condition, sequences are ordered from left to right, from the most to the least frequent one. Data are averaged over six sessions.

For the other pigeons, the behavioral variability obtained in the terminal link also was approximately similar with the Lag 5 and Lag 10 criteria, indicating that this variable per se was not likely a factor in the choice performances beyond the Lag 1 criterion. The percentage of correct sequences (or the probability of reinforcement), however, may not be ruled out as a potential source of control. As the lag criterion increased, the relative number of incorrect VARY sequences per reinforcer increased, and preference for REPEAT increased correspondingly.

The TOs at the end of the REPEAT terminal links also may have affected choice. Preference for terminal links delivering single versus multiple reinforcers is accentuated

when TOs follow the single-reinforcer terminal link (Poniewaz, 1984; cf. also Dunn, Williams, & Royalty, 1987; Logan, 1965; Snyderman, 1983). These studies together suggest that the addition of TOs in one terminal link does not change the direction of preference, but it leads to less extreme preference for that terminal link. An analogous effect may have occurred here such that the inclusion of TOs in the REPEAT terminal link may have attenuated the degree of preference for that alternative.

Another variable that was not constant was the delay to the first, and therefore to the four subsequent, reinforcers in each terminal link. Time to the first and subsequent reinforcers in terminal links of concurrent-chains

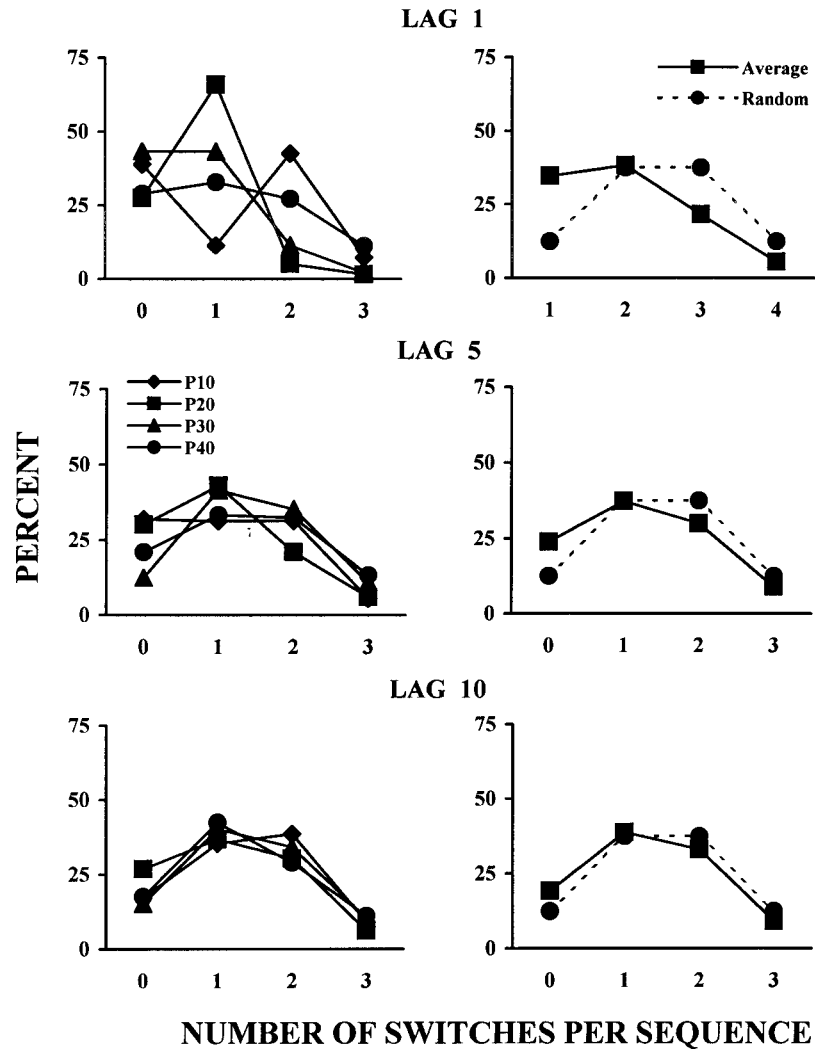


Fig. 6. Frequency distributions of the number of switches per sequence for the VARY performance in each condition of Experiment 1. Data are averaged over six sessions for Lag 1 and Lag 10 conditions, and over 12 sessions for Lag 5. The left columns indicate individual performances, and the right columns show average and random performances.

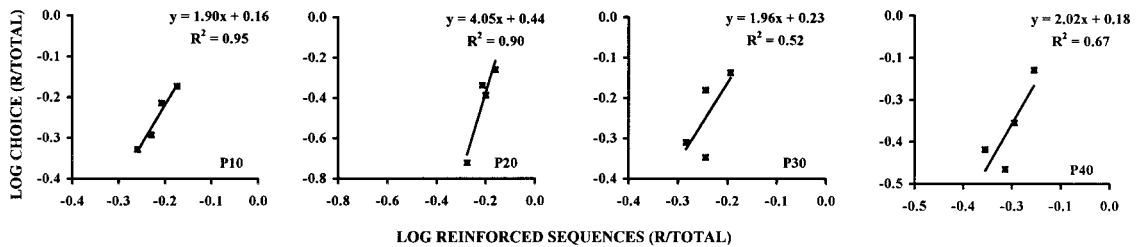


Fig. 7. Proportion of REPEAT choices in the initial links as a function of the proportion of REPEAT reinforced sequences in the terminal links of Experiment 1. Solid lines are fitted least-squares regression lines. Data are averaged over six sessions.

schedules can affect initial-link responding, with greater preference for terminal links that represent relatively greater delay reduction to reinforcement (e.g., Fantino, 1969; Fantino, Preston, & Dunn, 1993; Mazur, 1986; Shull, Spear, & Bryson, 1981). Although data on such delays were not obtained in this experiment, the general effect can be discerned from the extant data. During the Lag 1 condition, because the duration as well as the number of sequences per reinforcer in the VARY terminal link were comparable to that in the REPEAT terminal link (see Table 1), the delays to each reinforcer in either link were expected to be similar. With the two longer lag requirements, it is likely that the REPEAT terminal link involved relatively shorter delays to reinforcement because it was increasingly probable that a nonreinforceable VARY sequence would be emitted (see Table 1). The initial-link responding across the two keys is consistent with these observations in that preference for REPEAT increased with increased lag requirements. The second experiment investigated this issue.

EXPERIMENT 2

This experiment was performed to evaluate the effects of the obtained variability on preference in the absence of the confounding effects of delay to reinforcement and TOs. The interreinforcer intervals (IRIs) in the REPEAT terminal link were yoked to the IRIs in the VARY terminal link such that the REPEAT contingency closely replicated the delays to the first and subsequent reinforcers obtained with the VARY contingency. Because of this procedure, it also was possible to eliminate the TOs following the REPEAT terminal links.

METHOD

Subjects

Four experimentally naive homing pigeons (P50, P60, P70, and P80) were housed in individual cages, with water and grit freely available, and with a dark/light cycle in effect. Each was maintained at approximately 80% of its free-feeding body weight throughout the experiment.

Apparatus

The apparatus was slightly different than that in Experiment 1. The experimental chamber measured 35 cm long, 28 cm deep, and 28 cm high. The work panel contained four translucent keys, 2.5 cm in diameter, horizontally displayed on the wall, and located 18 cm above the floor. Keys 1 and 2, and Keys 3 and 4 were 3.5 cm apart, whereas Keys 2 and 3 were 7 cm apart. A Gerbrands food magazine delivered mixed grain through a 4-cm by 4-cm opening centered on the work panel, and located 4 cm above the floor. A white houselight was set on the middle of the opposite wall, 19 cm above the floor. A Son-alert® tone generator was not available and therefore was not part of the apparatus. The other aspects of the chamber were identical to those described for the chamber used in Experiment 1. All events were controlled by a 486 DX2 40 MHz microcomputer connected to the chamber by a MED-PC® interface system.

Procedure

The preliminary REPEAT/VARY training was as in Experiment 1. The pigeons then were exposed to concurrent-chains training that was similar to that in Experiment 1, with four exceptions. First, a VI 30-s schedule was in effect with the VARY contingencies such that each sequence produced one of the following consequences: (a) if the sequence met the lag criterion following the timing out of the current interval, a 3-s reinforcer was delivered; (b) if the sequence met the lag criterion, but the current VI had not elapsed, the feeder and the feeder light were operated for 0.5 s; and (c) if the sequence did not meet the lag criterion, a 5-s BO was initiated. A VI schedule also was superimposed with the REPEAT contingency such that: (a) a 3-s reinforcer followed LRRR sequences only when they were emitted after the current interval had elapsed; (b) if the LRRR sequence was emitted before the VI timed out, the feeder and the feeder light were operated for 0.5-s; and (c) any other sequence produced a 5-s BO. The critical feature of this arrangement was that the IRIs in the current REPEAT terminal links were yoked to the IRIs in the last VARY terminal link. To illustrate, if the first VARY reinforcer was delivered 35 s after the

Table 2

Total number of sessions, interreinforcer intervals, and number of reinforced sequences per reinforcer for the REPEAT and VARY terminal links in each condition of Experiment 2. Data are averaged over six sessions. Standard deviations are shown in parenthesis.

Subject	Condition	Sessions	Interreinforcer intervals (s)		Sequences per reinforcer	
			Repeat	Vary	Repeat	Vary
P50	Lag 1	62	36.2 (3.2)	31.9 (2.5)	5.3 (0.4)	5.0 (0.4)
	Lag 10	56	49.0 (9.4)	39.8 (7.1)	5.4 (0.8)	4.4 (0.3)
	Lag 1	17	35.3 (3.9)	32.0 (2.7)	4.6 (0.6)	4.6 (0.5)
P60	Lag 1	67	39.9 (3.7)	31.8 (2.0)	4.6 (0.2)	4.3 (0.4)
	Lag 10	30	44.1 (6.1)	31.2 (5.2)	6.1 (0.7)	4.9 (0.5)
	Lag 1	14	37.3 (0.6)	30.2 (0.2)	5.5 (0.2)	4.6 (0.3)
P70	Lag 10	63	59.2 (6.4)	43.7 (3.8)	10.3 (1.0)	5.2 (0.6)
	Lag 1	62	39.9 (2.3)	34.1 (2.2)	6.0 (0.6)	4.4 (0.4)
	Lag 10	41	49.7 (1.6)	38.1 (1.8)	7.6 (0.3)	4.2 (0.2)
P80	Lag 10	63	41.9 (23.2)	32.4 (3.8)	7.4 (1.7)	4.7 (0.6)
	Lag 1	56	31.1 (2.2)	27.8 (2.1)	5.9 (0.4)	5.1 (0.4)
	Lag 10	16	46.0 (3.8)	37.0 (3.8)	7.6 (0.8)	4.7 (0.3)

beginning of the terminal link, and the second, third, fourth, and fifth reinforcers were delivered 45 s, 20 s, 10 s, and 40 s after the previous one, respectively, the first REPEAT reinforcer also was programmed to occur 35 s after the onset of the terminal link, and the remaining four reinforcers were programmed to be delivered, following a correct sequence, 45s, 20 s, 10 s, and 40 s after the preceding one, respectively.

The second difference concerned the auditory stimuli. In the present experiment, a tone was not programmed in either terminal link. The third difference was that each session ended after six REPEAT and six VARY terminal links, excluding the warm-up ones (cf. Exp. 1). The final difference was that only two lag criteria, Lag 1 and Lag 10, were programmed in different conditions during the VARY terminal link. Table 2 shows the order of conditions and the number of sessions

at each condition for all pigeons. Other details of the procedure were as described in the first experiment.

RESULTS

The data in Table 2 show that the IRIs for VARY were slightly longer than the average IRI programmed (30 s). This occurred because the interval rarely timed out immediately after a correct sequence was emitted; consequently, after the current interval had elapsed, the emission of a correct sequence added time to the IRI for both REPEAT and VARY. This additional time was greater with Lag 10 than with Lag 1 due to the greater number of incorrect sequences in the VARY terminal link with the more restrictive requirement. Also, the IRIs in the REPEAT terminal links were consistently slightly longer (i.e., the unconditioned reinforcement rates were lower) than those in the VARY terminal links ($t = .526$, $p = .001$ for Lag 1; $t = 6.623$, $p = .001$ for Lag 10). A least-squares regression analysis, not shown here, revealed no systematic relation between rates of unconditioned reinforcement and preference.

Performance in the Initial Links

For each pigeon, the proportion of REPEAT choices increased when the lag criterion increased, as shown in Figure 8. Also, the differences between choice proportions in Lag 1 and Lag 10 conditions were more accentuated than in Experiment 1, probably due to the elimination of TOs in the REPEAT terminal link (cf. Dunn et al., 1987; Logan, 1965; Poniewaz, 1984; Snyderman, 1983).

Performance in the Terminal Links

Figure 9 indicates the U values for each pigeon across the three conditions. The U values for the REPEAT terminal link (open bars) were lower than those for the VARY terminal links (filled bars), and were not systematically affected by changes in the lag criterion. The U values for VARY tended to be higher under the Lag 10 criterion than under the Lag 1 criterion.

The percentage of correct sequences, shown in Figure 10, was calculated by dividing the number of sequences that met the REPEAT (or VARY) criterion, including sequences that produced the 0.5-s food presentation (conditioned reinforcer) and those

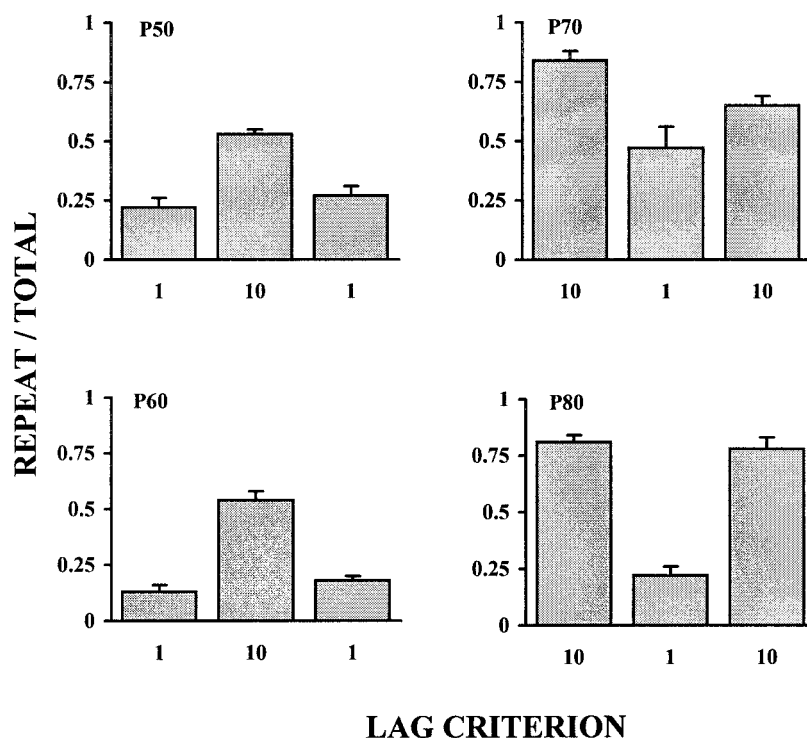


Fig. 8. Proportion of REPEAT choices in the initial links for each condition of Experiment 2. Data are averaged over six sessions. Error bars represent one standard deviation.

that produced the 3-s food presentation, by the total number of REPEAT (or VARY) sequences in a session, and then multiplying the result by 100. The percentage of REPEAT correct sequences (open bars) remained constant across conditions whereas the percentage of VARY correct sequences (filled bars) changed with the lag criterion. With the Lag 1 criterion, both terminal links produced high and similar percentages of correct sequences; with the Lag 10 criterion, a higher percentage of correct sequences was engendered by the REPEAT contingency than by the VARY one.

The results of Figures 9 and 10 indicate that stringent variability requirements produced greater variation in responding than did less stringent ones, but such greater variation was not necessarily accompanied by a higher frequency of sequences that met the requirements for reinforcement (see also Page & Neuringer, 1985).

Figure 11 shows frequency distributions of each of the 16 possible sequences in the VARY terminal link. As in the first experi-

ment, the Lag 10 condition produced flatter distributions than the Lag 1 condition. The percentage of total sequences represented by the four most frequently emitted ones varied as a function of the lag. In the Lag 1 and Lag 10 (averaged across determinations) conditions, respectively, the percentages were: for Pigeon P50, 68.2% and 39.2%; for Pigeon P60, 89.9% and 38.6%; for Pigeon P70, 70.4% and 59.6%; and for Pigeon P80, 51.3% and 40.1%. These results suggest, as in Experiment 1, that the pigeons' behavior varied only enough to meet the lag criterion, and with minimal switching between keys.

Figure 12 shows the relative frequency distributions of the number of switches per sequence. The left column indicates individual data and the right column shows average data as well as the binomial distribution predicted by random performance. The results replicated those found in Experiment 1. For all subjects, one-switch sequences were either the most frequent ones (Lag 1) or occurred as often as two-switch sequences (Lag 10). Average performance tended to deviate from

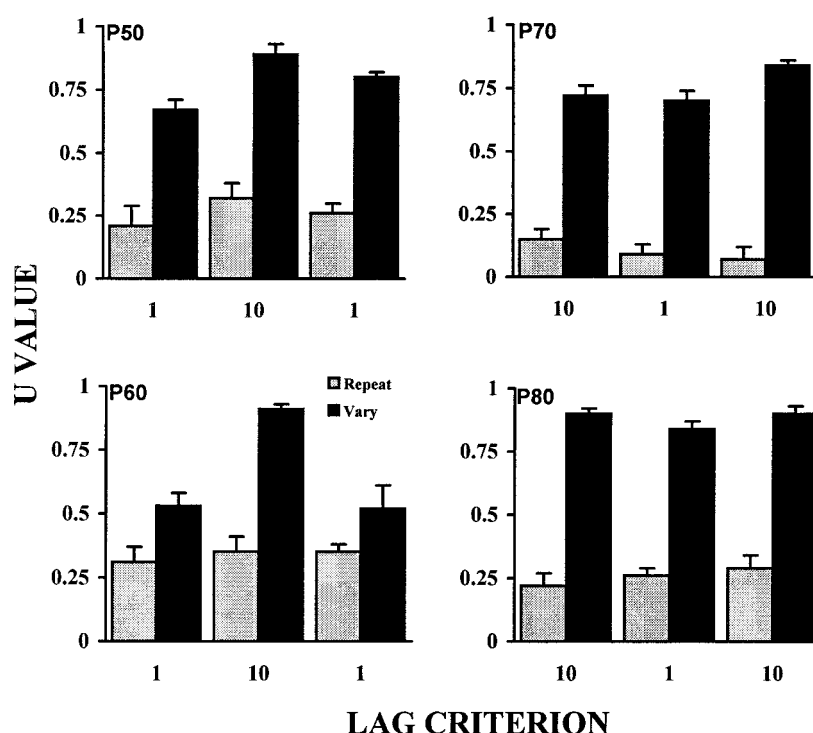


Fig. 9. U values in the REPEAT (open bars) and VARY (filled bars) terminal links for each condition of Experiment 2. Data are averaged over six sessions. Error bars represent one standard deviation.

random in the Lag 1 condition in that one-switch sequences were over represented and two-switch sequences were under represented. With the Lag 10 requirement, switching was close to random.

Choice versus Performance in the Terminal Links

Figure 13 shows the relation between the log proportion of REPEAT choices and the proportion of reinforced (either by conditioned and unconditioned reinforcers) sequences in the REPEAT terminal link. As in Experiment 1, preference for the REPEAT contingency varied directly with the proportion of REPEAT reinforced sequences. Again, the slope values indicate that changes in preference were greater than changes in reinforced sequences. Variance in the data accounted for by the fitted functions averaged 92%.

The log proportion of REPEAT choices also was analyzed as a function of the log proportion of U values in the REPEAT terminal link. Contrary to Experiment 1, an inverse relation was found between preference for the

REPEAT terminal link and the degree of behavioral variability for the pigeons exposed to the Lag 1–Lag 10–Lag 1 order of conditions ($R^2 = .73$ for Pigeon P50, and $R^2 = .80$ for Pigeon P70).

DISCUSSION

The increased preference for the REPEAT terminal link as the lag requirement increased replicated the effect obtained in the first experiment. Here, however, the increase occurred without the confounding effects in Experiment 1 of either the added TO at the end of the REPEAT terminal links or the delays to unconditioned reinforcement in the terminal links. Although the IRIs for REPEAT were slightly longer than those for VARY, this effect was observed similarly with the Lag 1 and Lag 10 conditions. Also, although the IRIs were longer with Lag 10 than with Lag 1, this effect occurred for both REPEAT and VARY terminal links. Thus the IRI bias was in the same direction in both terminal links but performance still tracked the lag contingency requirement, suggesting that the IRI bias was

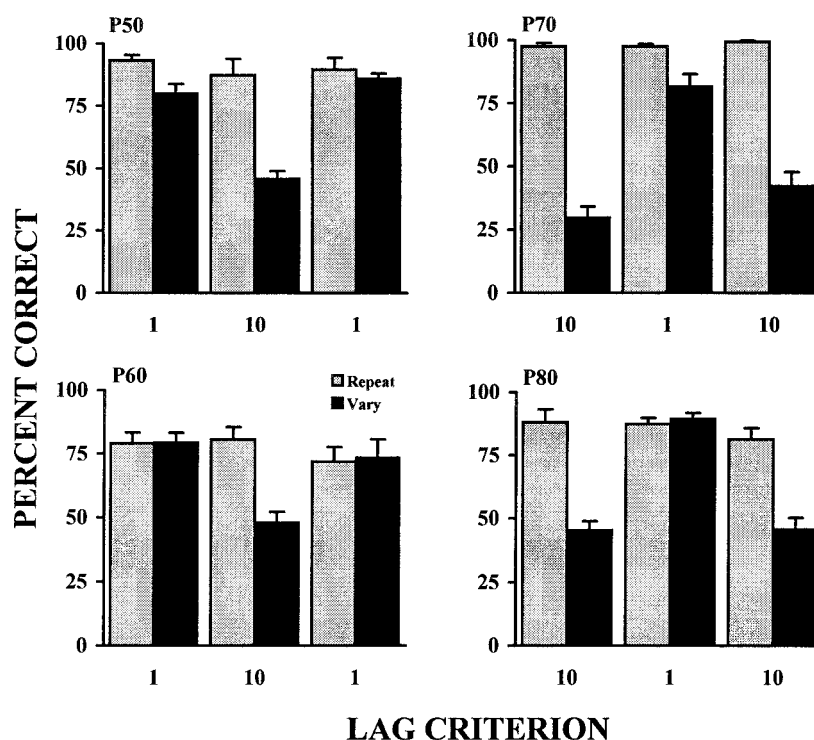


Fig. 10. Percentage of reinforced sequences in the REPEAT (open bars) and VARY (filled bars) terminal links for each condition of Experiment 2. Data are averaged over six sessions. Error bars represent one standard deviation.

not the controlling variable of the performance.

All pigeons preferred the VARY terminal link under the Lag 1 condition. At first glance, it could be argued that such preference resulted from a relatively greater reduction to conditioned reinforcement in the VARY terminal link. That is, the pigeons could meet the Lag 1 criterion by emitting only the two sequences with no switches (i.e., LLLL or RRRR). No switching sequences imply shorter delay to reinforcement than sequences with one or more switches, as was the case with the REPEAT sequence (i.e., LRRL). Several factors, however, challenge this argument. First, the switching analysis revealed that sequences with one or more switches corresponded to about 80% of the total sequence occurrences (see Figure 12). Second, because the number of sequences per reinforcer and the probability of conditioned plus unconditioned reinforcers were similar in the REPEAT and VARY terminal links, as shown in Table 2 and Figure 10, respectively, the delays to reinforcement should not differ

under both contingencies. It follows, then, that the higher frequency of VARY choices in the Lag 1 condition may reflect control by variation per se. This latter result is consistent with the finding of preference for variation in a number of investigations of choice between fixed versus variable schedules (e.g., Fantino, 1967; Mazur & Romano, 1992).

Whether the U values were a good predictor of preference depended on the order of lag-criterion presentation. In the order of Lag 1–Lag 10–Lag 1, preference for REPEAT varied directly with U value in the VARY terminal link. This relation did not hold for the opposite order of lag-criterion presentations. That is, with the Lag 10–Lag 1–Lag 10 order of conditions, changes in the lag criterion were accompanied by changes in preference even though the U values remained high and similar across conditions. Although these results, by themselves, do not necessarily rule out variation as a controlling variable of choice, they certainly suggest that other, indirect, variables were affecting preference for variation.

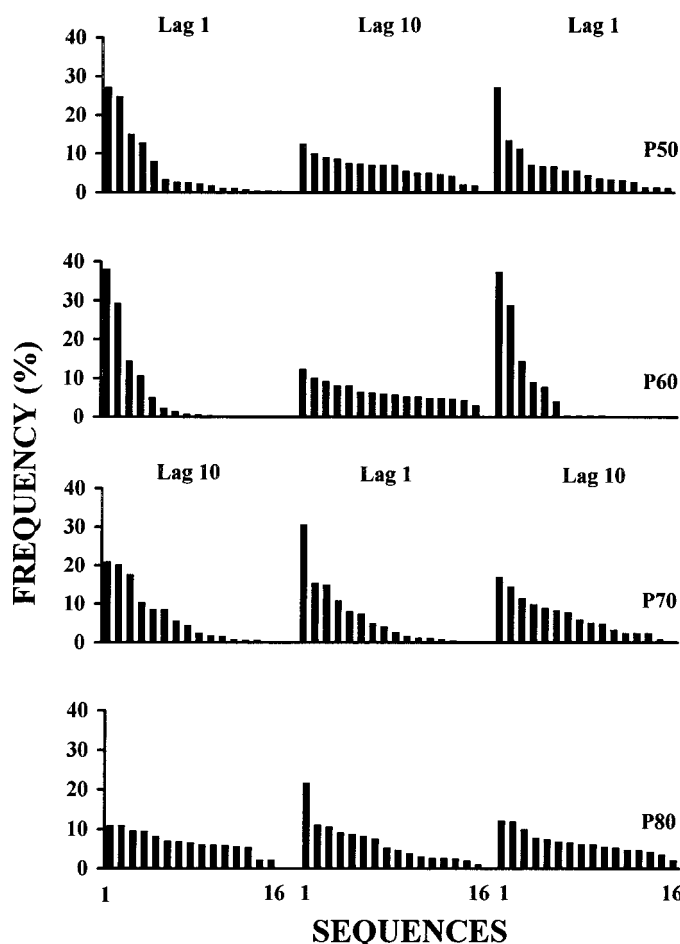


Fig. 11. Frequency distributions of the 16 possible sequences in the VARY terminal link in Experiment 2. In each graph, and for each condition, sequences are ordered from left to right, from the most to the least frequent one. Data are averaged over six sessions.

Under the Lag 1 condition, the percentage of correct sequences in the REPEAT and VARY terminal links was approximately equal. Under the Lag 10 condition, there were about twice as many correct response sequences in the REPEAT terminal link. Thus preference for the REPEAT terminal link covaried with the relative percentage of correct REPEAT sequences. These correct response sequences represent a mix of those followed by unconditioned reinforcers according to the VI schedule and those followed by conditioned reinforcers (0.5-s hopper presentations). This raises the possibility that the indirect variable of greater probability of conditioned reinforcement in the REPEAT terminal link was responsible for the increased preference for

that link during the Lag 10 condition. Such an interpretation, however, is challenged by results reported by Schuster (1969). In his Experiments 3 and 4, pigeons responded on concurrent-chains schedules in which one terminal link provided only unconditioned reinforcers and the other provided both unconditioned reinforcers and additional stimuli that were paired with those unconditioned reinforcers (which he labeled SEs). He found that "after continued exposure to the SE schedule, it was avoided by 7 of 9 birds" (p. 220). In relation to the present results, Schuster's data suggest that the larger number of conditioned reinforcers in the REPEAT terminal link would decrease, rather than increase, preference for that link.

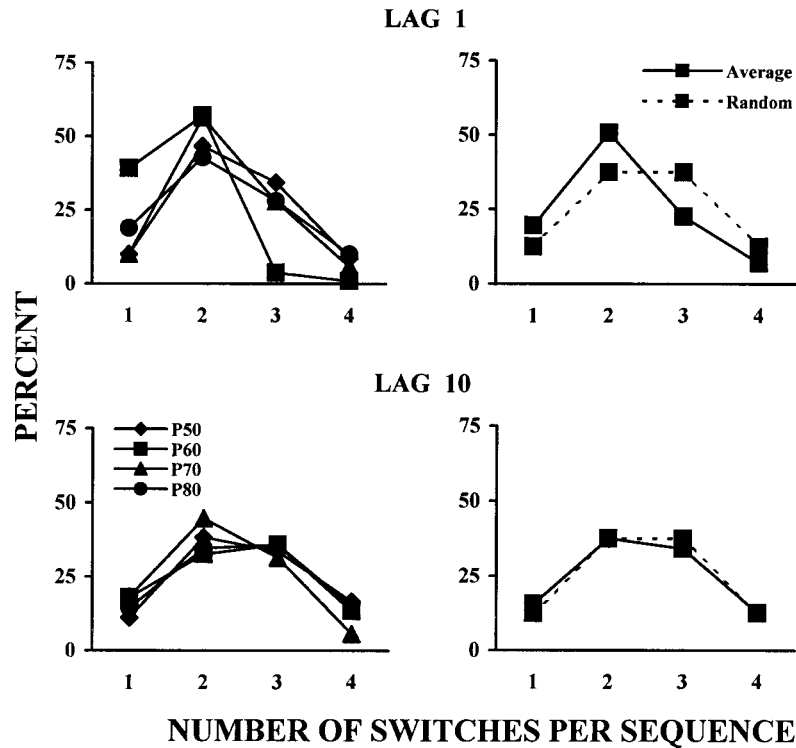


Fig. 12. Frequency distributions of the number of switches per sequence for the VARY performance in each condition of Experiment 2. For Pigeons P50 and P60, data are averaged over 12 sessions for Lag 1, and over six sessions for Lag 10; for Pigeons P70 and P80, data are averaged over six sessions for Lag 1, and over 12 sessions for Lag 10. The left columns indicate individual performances, and the right columns show average and random performances.

Another indirect controlling variable may be represented by delay to reinforcement. Although the delays to unconditioned reinforcers were approximately similar in both terminal links, the same may not be true with respect to the delays to conditioned reinforcers. In accord with the delay reduction hypothesis (Fantino, 1969; Fantino et al., 1993),

it might be argued that the increase in preference for the REPEAT terminal link, obtained with the Lag 10 criterion, occurred because the high percentage of incorrect sequences probably was accompanied by relatively longer delays to the conditioned reinforcers. With the Lag 1 criterion, however, because the delays to reinforcement were

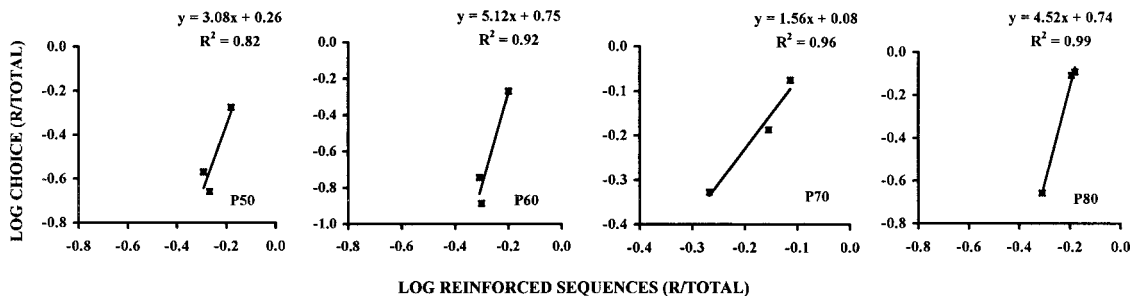


Fig. 13. Proportion of REPEAT choices in the initial links as a function of the proportion of REPEAT reinforced sequences in the terminal links of Experiment 2. Solid lines are fitted least-squares regression lines. Data are averaged over six sessions.

comparable across terminal links, preference for either contingency should not develop. The present findings are consistent with the first (Lag 10), but not with the second (Lag 1), prediction.

GENERAL DISCUSSION

Using concurrent-chains schedules, these two experiments support and extend Neuringer's (1992) suggestion that contingencies on varying and repeating can affect choice. The control of responding by contingencies requiring response stereotypy or response variability was similar to that previously reported (e.g., Cohen et al., 1990; McElroy & Neuringer, 1990; Neuringer, 1991, Experiments 2 and 3; Page & Neuringer, 1985). In addition, behavioral variation tended to change directly with the degree of variability required by the reinforcement contingencies (cf. Morris, 1989; Page & Neuringer, 1985). Preference for either of the two contingencies was directly related to the variability requirement.

Directly imposing the variability requirement in a choice procedure also brings into play several indirect variables within the concurrent-chains procedure that may have contributed to the preferences. One (differences in reinforcement rate) was controlled in the first experiment and others (unconditioned reinforcement delay and TO) were controlled in the second experiment. With these variables held constant, preference for the repeat terminal link increased with increasing variability requirements in the VARY terminal link.

A related but different question is whether repetition and variation reduce to other behavioral processes. For example, choice could be related to response switching, percentage of correct sequences, reinforcement delay, or all of the above. In the case of switching, Machado (1997) argued that variability requirements operate directly on switching behavior such that variation is only a by-product of such a process. Applying this argument to the present data, which indicated that increases in the lag criterion increased the number of switches per sequence (see Figures 6 and 12), it is plausible to assume that switching may have influenced choice. This effect might occur because increased switching functionally increases the number of responses. Hunzink-

er et al. (1998) noted, for example, that sequences with no switches (e.g., RRRR) contain only four pecking responses whereas those with three switches (e.g., RLRL) comprise seven responses: four pecking and three switching responses. Thus increases in the number of responses could affect choice by either the effort involved or the inherently more frequent reinforcement of the shorter sequences.

In the case of percentage of correct sequences, in both experiments, increasing the lag requirements in the terminal links decreased the percentage of reinforced sequences for all subjects. As a result, it is difficult to rule out the percentage of reinforced sequences as a possible source of control over choice when VARY and REPEAT contingencies operate. If increasing the lag requirement does decrease the percentage of reinforced sequences, then the resistance to change of those sequences also might be weakened because responding correlated with less probable reinforcement is less resistant to change than responding where reinforcement is more probable (Nevin, 1974). Thus, under this circumstance, the less variable responding would be more resistant to change than would be the more variable.

At first glance, these latter findings appear to contradict those of Doughty and Lattal (2001), who showed that variable response sequence production is more resistant to change than repeat sequence production. Doughty and Lattal, however, held reinforcement probability constant for the repeat and vary sequences, thereby eliminating reinforcement differences as a factor in their results. Their results, along with an observation of Nevin and Grace (2000) and the present data, do raise a theoretical question about the relation between resistance to change of repeat and vary sequences and choice. Nevin and Grace concluded that preference and resistance to change are positively correlated. As noted, Doughty and Lattal concluded that varied response sequences are more resistant to change than repeated ones. Thus their data would predict that, under the parameters of their experiment, there would be preference for the VARY requirement. The present results, however, may qualify this prediction in the following way. Because there was not always greater preference for

the VARY requirement over the REPEAT requirement during each of the different lag requirement conditions of the present experiment, greater resistance to change would be predicted to occur only under contingencies giving rise to greater preference for the VARY condition. Furthermore, the relation may not be a simple either-or one but rather may be a graded function of the degree of preference or, going the other way, resistance to change.

Although delays to either unconditioned or conditioned reinforcement were not measured, the analysis of the switching responses as well as the percentage of reinforced sequences suggest that increases in the lag requirement were probably followed by relatively greater reduction in time to REPEAT reinforcement. As a consequence, the delay reduction hypothesis would predict an increasing preference for the REPEAT terminal link (Fantino, 1969; Fantino *et al.*, 1993). It is important to note, however, that when the terminal links comprise multiple reinforcers, the delay to each reinforcer, not only the delay to the first reinforcer (as in Fantino's studies), may differentially contribute to preference. In a study by Shull *et al.* (1981, Experiment 2), for example, when the delays to the first and third reinforcers were maintained constant, preference decreased as the delay to the second reinforcer increased. A similar effect was obtained when four reinforcers were available and only the delay to the third reinforcer was manipulated. Also, the magnitude of changes in preference was greater with manipulations of the delay to the second than to the third reinforcer (see also Mazur, 1986; McDiarmid & Rilling, 1965). These findings indicate that measuring time to reinforcement from the onset of the choice period to the delivery of the last reinforcer available in multiple-reinforcers terminal links may not produce results comparable to those obtained with standard-delay studies in which time to the first reinforcer is the critical variable.

Although the present results suggest that the indirect variables discussed so far may be better predictors of preference between varying and repeating behavior than the U values, they do not rule out behavior variation *per se* as a contributor to preference. Two aspects of the present data suggest that variation may

be a critical variable. First, when delay to unconditioned reinforcement was held constant across terminal links, preference for REPEAT varied inversely with the U values in the VARY terminal link for 2 pigeons (P50 and P60). Second, and most important, greater preference for VARY was observed for all pigeons in both experiments when the Lag 1 condition was in effect. That is, when switching, probability of reinforcement and delay to reinforcement were constant such that the terminal links differed primarily with respect to varying or repeating behavior, preference for variation occurred. This finding may be related to that reported by Catania (1975, 1980). In his studies, pigeons were exposed to a concurrent-chains schedule and required to choose between a terminal link with two keys correlated with concurrent fixed-interval (FI) schedules (free choice) and a terminal link with only one FI key (forced choice). The values of the FI schedules were identical in both terminal links. This arrangement is comparable to that of the Lag 1 condition. The forced-choice terminal link resembles the REPEAT terminal link in that both included only one alternative to reinforcement, responding on a single key or emitting a specific sequence, respectively. The free choice and the VARY terminal links comprised a greater number of alternatives to reinforcement, responding on two keys or emitting up to 16 different sequences (although the pigeons developed a stereotyped pattern of three or four sequences), respectively. Also, the probability and delay to reinforcement were identical in both free- versus forced choice, and REPEAT versus VARY, terminal links. With both arrangements, as with Catania's experiments, preference for the terminal link providing variable alternatives to reinforcement was observed.

One question that follows from the present results is that of why a systematic relation between preference and behavior variability was not observed with more stringent lag criteria, that is, the question of why preference for variation decreased as higher levels of behavior variability were required for reinforcement. The findings from the present experiment suggest that when behaving repetitively or variably are similarly adaptive (as in the Lag 1 condition), preference for variation is observed. But when the task of generating new

response sequences increasingly leads to less profitable consequences (lower probability of reinforcement, longer delays to reinforcement), as in the Lag 5 and Lag 10 conditions, preference for repetition progressively increases.

The present results also revealed higher-order stereotypies in the VARY terminal link. That is, variation in behavior was just enough to meet the contingency. Although 16 different sequences could be emitted with similar frequencies, the pigeons developed a predominant pattern of about three (in the Lag 1 condition) or eight (in the Lag 5 condition) sequences, an efficient strategy in those conditions. With the most stringent criterion (Lag 10), however, sequence stereotypy was not observed in that the pigeons tended to emit all sequences with equal probability. These findings are consistent with previous reports of higher-order stereotypies with humans (Barret, Deitz, Gaydos, & Quinn, 1987; Schwartz, 1982b). Considering that stereotypy occurred within a context of variable behavior, it can be argued that reinforcement maintained variability while at the same time selected particular instances of behavior within the range of variation. That is, because reinforcers lead to repetition, it is not surprising that repetitions occurred in both terminal links. But the occurrence of repetitions also depended on the extent to which they were allowed by the contingency. Neuringer (1993) demonstrated that reinforcement could promote variation and selection simultaneously. Another possibility is that stereotypy may reflect efficient responding, as suggested by Schwartz (1982a).

In both of the present experiments, during exposure to a shorter lag requirement after exposure to a longer one, variability tended to remain as high or nearly as high under the shorter requirement as it was under the preceding longer one. This probably was because the previously established performance still met the new, shorter criterion. Indeed, it is possible that under these conditions the shorter lag contingency may not even be contacted. These results are related to a finding reported by Hunziker et al. (1998). Rats completed a fixed-ratio (FR) 4 requirement with two operanda available for responding. If the FR 4 condition was preceded by a condition requiring a sequence of four responses under

a Lag 4 contingency, responding under the subsequent FR 4 schedule was more variable than if the FR 4 requirement was not preceded by the Lag 4 requirement. The reinforcement rates between the FR and the lag requirement condition were equated through a yoking procedure. Unlike the present experiment, however, Hunziker et al. found that the variability decreased with continued exposure to the FR schedule after the lag requirement condition. This difference at least in part may be because, contrary to Hunziker et al.'s procedure, in which sequence variation was no longer required when contingencies were changed from Lag 4 to FR 4, in the present procedures some degree of variation still was required after contingencies were changed from a longer to a shorter lag criterion (e.g., from Lag 10 to Lag 1).

More generally, the present findings also bear on an understanding of creativity. Creative behavior corresponds to unique combinations of previously selected responses evoked by a new environment (Donahoe & Palmer, 1994). When the environment changes and novel forms of behavior are required for reinforcement, the already selected responses set a context for new combinations. The greater the variety of responses available in the behavioral repertoire of an individual, the greater the number of possible combinations, that is, the more "creative" the behavior is labeled. Thus one way to promote creative behavior is by arranging contingencies that select behavioral variability. If, however, the task of generating new behavior becomes too difficult and there are alternatives to varying behavior, the present data suggest that behaving creatively may be less preferred. Given the benefits of creative behavior, for example, scientific and technological innovation, it becomes important, through experimental research like that described here, to better understand the controlling variables of choosing creative over repetitive behavior.

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